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Date: July 7, 2010 Name: Jasper W. Dockrey, Reg. 33,868 Signature: /Jasper W. Dockrey/

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Appln. of: Moriceau, et al.		
Appln. No.:	10/565,621	Examiner: Reema Patel
Filed:	July 25, 2006	Art Unit: 2812
For:	STACKED STRUCTURE AND PRODUCTION METHOD THEREOF	Confirmation No.: 2319
Attorney Docket No:	9905/37 (BIF116044US)	

DECLARATION UNDER 37 C.F.R. §1.132

Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

Dear Sir:

Declarant, Dr. **Stéphane RENARD**, herby states as follows:

1. I hold a PhD degree in optoelectronics, which I received in 1983 from Institut National Polytechnique de Grenoble (Grenoble Institute of technology).

2. I am the founder and presently the CTO of TRONIC'S Microsystems.

3. As shown in my short CV attached as Exhibit A, I have authored and co-authored technical publications, in the field of semiconductor fabrication for optoelectronics or MEMS technology.

4. I have reviewed the pending U.S. patent application identified above, ("the '621 application") (published U.S. application attached as Exhibit B), and the Office Action dated January 7, 2010 (attached as Exhibit C). I have further reviewed the proposed changes

to the specification and drawing, including the proposed FIG. 7, submitted with the applicants' Response of September 11, 2009 (attached as Exhibit D). I have also reviewed U.S. Patent 4, 653,326, which is the U.S. counterpart of French Patent No. FR 2,558,263, referenced in the '621 application at paragraph 0010 (attached as Exhibit E). I consider myself to be a person skilled in the art in the subject matter disclosed and claimed in the '621 patent application. I have been asked to give opinions on the matters recited in this Declaration and I believe that I am qualified by education and experience to do so.

5. Based on my review of the specification and drawing of the '621 application, and the pending claims 1, 5-8, and 11-26, as shown in the Response, I do not agree with the Examiner's assertion on pages 2 to 4 of the Office Action that the specification does not enable a person skilled in the art to practice the invention recited by claim 1. In particular, it is my belief that one skilled in the art, using the teaching of the '621 application, could practice the claimed method in which a sacrificial layer is at least partially eliminated to expose a surface portion of a first bonded plate, such that the surface portion at least partially faces the second bonded plate. I further believe that there is support in the specification of the '621 application for a structure as shown by the proposed additional figure (FIG. 7), in which a portion of the sacrificial layer removed to expose part of the surface of the first plate.

6. The '621 application describes wafer level fabrication of microstructures, which involve processing methods commonly used in microelectronics fabrication, such as thermal oxidation, thin film deposition, and etching of layers using lithography techniques. In particular, the application describes the fabrication of micro-electro-mechanical system (MEMS) devices that can include various sensors and actuators.

7. The MEMS devices can be fabricated using a silicon-on-insulator (SOI) substrate. The SOI substrate is produced by bonding silicon plates together using molecular bonding. An oxide layer is formed on one of substrates prior to bonding. A thin silicon layer over the oxide layer is then produced by thinning or fracturing one of the substrates.

8. Mobile or deformable mechanical structures can be produced from the SOI substrate by machining the top silicon film and freeing the structure by chemically etching the whole or a portion of the underlying oxide layer. The mechanical structure can be created by plasma etching the thin surface layer of silicon and chemically etching the silicon oxide layer using hydrofluoric acid (HF).

9. It is known by those skilled in semiconductor fabrication that sacrificial layers can be used in which the layer is formed on one of the substrates, and later, all or part of the layer is removed. The sacrificial layer is a layer that can be eliminated subsequently, such as during use of the stacked structure to fabricate a mobile or deformable component. The sacrificial layer has a chemical composition that is different from the underlying layer, such that it can be differentially etched with respect to the underlying layer.

10. MEMS devices that include moving components, can be formed with an SOI structure by eliminating a portion of the oxide layer underlying the silicon thin layer. Such MEMS devices are described in numerous references, including French Patent No. FR 2,558,263, referenced in the '621 application at paragraph 1101(U.S. counterpart attached at Exhibit E). The device is formed by removing the underlying oxide layer to free the thin silicon layers overlying the oxide layer. In an accelerometer, for example, as shown in FIG. 2 of Exhibit E, a cantilevered silicon beam (16) is formed that is suspended over a recess (14).

11. The '621 application describes a problem in the fabrication of MEMS devices in which sticking prevents the freeing of the silicon layer after removing the underlying oxide layer. In the case of an accelerometer, the sticking problem prevents the silicon beams from moving freely, as they must in order for the accelerometer to function properly.

12. To overcome the sticking problem, the '621 application describes a technique in which a structured surface is formed prior to forming the oxide layer described above. The structuring of the surface makes it uneven so that it will not stick to another surface.

Thus, when a portion of the oxide layer is removed, the exposed silicon surfaces will not stick together. In the case of an accelerometer, the cantilevered silicon beam, such as that discussed above, will not stick to the underlying silicon surface, but will be free to move in the vertical direction with respect to the horizontal axis of the beam.

13. I understand the '621 application to describe the following process (where corresponding paragraph numbers of the '621 application appear in parenthesis):

A. the surface of a first silicon plate, or both the first and second silicon plates (¶0069), is structured by roughening (¶0052) or nitriding (¶0065) or other chemical treatment (¶¶0066-67)

B. a sacrificial layer, such as an silicon oxide layer, is formed on the first silicon plate (¶0056) or both the first and second silicon plates (¶0070)

C. a second silicon plate is bonded to the first silicon plate (¶0058)

D. a heat treatment is applied to consolidate the interface (¶0060)

E. a thinning process may be carried out to thin one of the silicon plates (¶0061)

F. the sacrificial layer may be locally removed to create mobile portions of a MEMS device (¶0068)

G. it is also described that part of the sacrificial layer can be etched before bonding and the mobile portions of the MEMS device can also be formed before bonding (¶0062)

H. a lithography process can be used to define portions of the sacrificial layer and these portions can be etched away from the surface of the first silicon plate using the lithography mask as an etch mask (¶0063)

14. Thus, according to the '621 application, a non-continuous sacrificial layer can be formed by localized deposition or by etching the sacrificial layer on the silicon plate (¶0071). I understand this to mean that either a selective deposition process is used to deposit the sacrificial layer in only certain surface regions on the silicon plate, or a localized etching process, such as defined by a lithographic mask, is carried out to remove portions of the sacrificial layer from the surface of the silicon plate.

15. The concept of etching the sacrificial layer is described in the context of various embodiments of the invention. For example, the '621 application describes that:

> "It is clear that a non-continuous sacrificial layer may be obtained, for example by localized deposition or by etching; this enables areas already opened up to be defined in the stacked structure." (¶0071)

The localized etching and deposition processes described in the '621 application are well known semiconductor fabrication techniques. In the context of the '621 application, I believe that there is a description of the formation of a structure such as that shown in the proposed FIG. 7, submitted with the Response. Thus, when the two silicon plates are bonded together, the sacrificial layer will not extend entirely across the interface between the two plates. Because the sacrificial layer is either selectively formed in certain regions, or portions are removed, the silicon surfaces of the plates will be exposed to each other in certain areas of the interface.

16. According to the '621application, the process of removing at least a portion of the sacrificial layer on the structured silicon surface prevents the plates from sticking together. Once the portion of the sacrificial silicon oxide layer is removed, the two silicon surfaces face each other in the region where the silicon oxide layer was removed. In the terminology used in the '621application, the roughened portion of the first plate is opposite to the second plate, with a space between the roughened portion of the first plate and the second plate. I understand the meaning of the term "faces" as it appears in the application as describing a situation in which, because at least part of the silicon oxide layer has been

removed, and the structured surface of one plate is open to the other plate, without any intervening layer between the two plates.

18. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

July 6th, 2010

Dr Stéphane RENARD

EXHIBIT A

Stephane RENARD is the founder and CTO of TRONIC'S Microsystems.
He received its engineering degree from Ecole Centrale des Arts et Manufactures in Paris (ECP 79) and his PhD degree in optoelectronics from Institut National Polytechnique de Grenoble (1983). In 1983, he joined LETI (CEA) where he participated to various R&D projects and technology transfers in optoelectronics. From 1993 to 1997, he was the LETI micro-sensors and MEMS R&D team manager before creating in May 1997, TRONIC'S Microsystems the first European private company specialised in the manufacturing of dedicated SOI MEMS.

List of publications in the field of Optoelectronics and MEMS technology

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Transforming MEMS concepts into reliable products: a statistical model and design validation approach, Gaff, V.; Renard, MST News, 2005

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EXHIBIT B

US 20060281212A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2006/0281212 A1**

Moriceau et al. (43) **Pub. Date: Dec. 14, 2006**

(54) **STACKED STRUCTURE AND PRODUCTION METHOD THEREOF**

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Publication Classification

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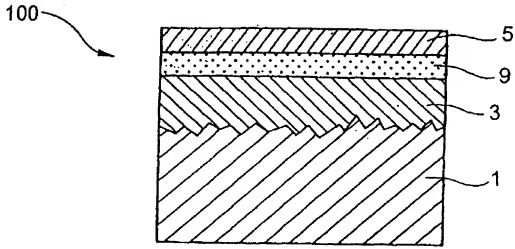
H01L 21/00 (2006.01)

(52) **U.S. Cl.** **438/48**

(57) **ABSTRACT**

The invention relates to a method of producing a stacked structure. The inventive method comprises the following steps consisting in: a) using a first plate (1) which is, for example, made from silicon, and a second plate (5) which is also, for example, made from silicon, such that at least one of said first (1) and second (5) plates has, at least in part, a surface (2; 7) that cannot bond to the other plate; b) providing a surface layer (3; 8), which is, for example, made from silicon oxide, on at least one part of the surface (2) of the first plate and/or the surface (7) of the second plate (5); and c) bonding the two plates (1; 5) to one another. The aforementioned bonding incompatibility can, for example, result from the physicochemical nature of the surface or of a coating applied thereto, or from a roughness value (r_2, r_7) which is greater than a predetermined threshold. The invention also relates to a stacked structure produced using the inventive method.



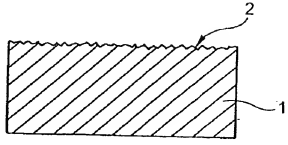


Fig.1

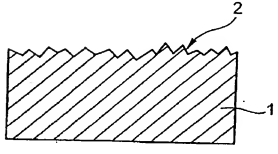


Fig.2

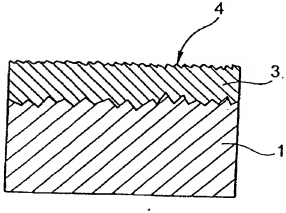


Fig.3

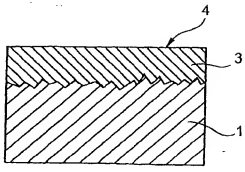


Fig.4

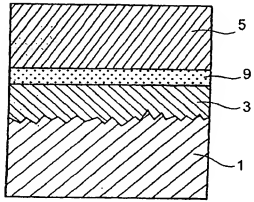


Fig.5

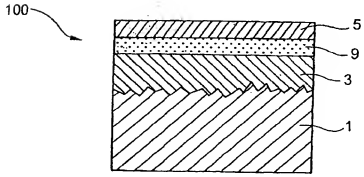


Fig.6

STACKED STRUCTURE AND PRODUCTION METHOD THEREOF

BACKGROUND OF THE INVENTION

[0001] This application claims the benefit of priority from French Application No. 0308865, filed Jul. 21, 2003, which is incorporated herein by reference.

[0002] The general field of the invention is that of wafer level fabrication of microstructures, for example by means of micromachining or chemical processing techniques used in microelectronics (deposition and etching of layers, photolithography and so on). The invention relates more particularly to certain microstructures of the micro-electromechanical system (MEMS) type, such as various sensors and actuators, which are obtained by freeing mobile portions (for example membranes or seismic masses).

[0003] To obtain such microstructures, the starting material may be of the silicon-on-insulator (SOI) type, for example, which usually comprises a surface layer of silicon and an underlying buried layer of silicon oxide SiO_2.

[0004] There are several ways to fabricate the SOI material. See, for example, "Semiconductor Wafer Bonding", Q. Y. Tong and U. Goesele, Science and Technology, ECS Series, John Wiley, New Jersey 1999. However, most SOI materials are nowadays fabricated by the molecular bonding technique. For example, two silicon plates are bonded together by the molecular bonding technique, at least one of the two plates having a surface layer of silicon oxide. The silicon oxide layer is usually produced by thermal oxidation. One of the two plates is then thinned. An SOI type structure is obtained in this way.

[0005] Several techniques for obtaining a thin layer may be used (in the context of the present invention, a layer is regarded as thin if its thickness is less than a few tens of microns). For example, a first technique is thinning (mechanical thinning by planing and/or smoothing, and/or chemical thinning, and/or mechanical-chemical thinning). A second technique uses fracture in a fragile area created at a certain depth in one of the two plates, prior to said molecular bonding, for example by implanting one or more gaseous species; the patent application FR-2 681 472 discloses a method of the above kind, which at present is known as the "Smart-Cut®" method (see, for example "The Generic Nature of the Smart-Cut® Process for Thin-film Transfer", B. Aspar et al., Journal of Electronic Materials, Vol. 30, No 7, 2001). These methods are very suitable for obtaining thin surface layers of silicon, usually less than 2 μm thick.

[0006] It is possible to produce mobile or deformable mechanical structures from this SOI material, for example by machining the top silicon film and freeing the structure by chemically etching the whole or a portion of the underlying oxide; for example, the mechanical structure is created by plasma etching the thin surface layer of silicon and chemically etching the silicon oxide layer using hydrofluoric acid (HF).

[0007] In the context of the present invention, a layer forming part of a stacked structure is referred to as a sacrificial layer when it can be eliminated subsequently, for example during use of the stacked structure to fabricate a component having a mobile or deformable portion. The material constituting a sacrificial layer is therefore different, from the chemical or crystallographic point of view, from the material constituting the non-sacrificial layers, i.e. the layers intended to remain after eliminating the sacrificial layer. For example, if the stacked structure is made from an SOI material, the silicon oxide layer serves as a sacrificial layer and the silicon layers serve as non-sacrificial layers.

[0008] This process is relatively simple to use and produces a variety of microstructures.

[0009] Pressure sensors of high quality may be produced in this way, for example.

[0010] The accelerometer disclosed in the patent FR 2 558 263 may be cited as another example of this kind of microstructure and comprises, within a thin layer, a first portion cut out from the thin layer and a second portion consisting of the remainder of the thin layer, the first portion being connected to the second by means of flexible beams allowing the first or sensitive portion to move with a certain amplitude in the plane of the thin layer. This device is used to measure acceleration of any system to which it is attached by means of a variation in electrical capacitance caused by said movement.

[0011] Other detailed examples of such microstructures can be found in "SOI 'SIMOX'; from bulk to surface micromachining, a new age for silicon sensors and actuators", B. Diem et al., Sensors and Actuators, Vol. A 46-47, pages 8 to 16 (1995).

[0012] However, fabrication of such microstructures runs up against the following problem. During the production of the structure, and in particular at the time of drying the rinsing liquid after chemical etching with hydrofluoric acid, capillary forces between the surfaces and the liquid are very high and lead to partial or total sticking of the freed structures; another cause of sticking is a solid deposit which can be produced by said drying. In the case of the accelerometer described above, for example, this leads to the beams sticking to the substrate constituting the bottom of the cavity containing the device, which obviously prevents the beams from moving as intended in response to acceleration of the system.

[0013] The SOI structure fabrication techniques referred to above lead to interfaces between the surface layer of silicon and the buried oxide, and between the buried oxide and the substrate that are not particularly rough. This sticking problem is aggravated in that nowadays SOI structures are produced with very smooth interfaces; the thinner the oxide film, and the larger the structures to be freed, the greater the problem.

[0014] In order to avoid these problems of unwanted sticking, it is necessary to take important precautions, which make the freeing process complex, costly and difficult to control. Moreover, for reasons of reliability, such unwanted sticking of facing faces within MEMS components after the components go into service has to be prevented.

[0015] A first prior art means of preventing such sticking consists in reducing the bonding energy of the freed layer and the substrate. However, these techniques employ methods of chemical preparation of the surfaces that are incompatible with the high temperatures usually required for subsequent MEMS fabrication steps. For more details, see

"Suppression of Stiction in MEMS", C. H. Mastrangelo, Proceedings of the Materials Research Society Seminar, Vol. 605, 2000.

[0016] A second prior art way to prevent this sticking is to make the effective area of contact small when these two surfaces move toward each other. A method of this kind is disclosed in the patent FR 9 508 882. It consists in holding the freed layer and the substrate at a distance by etching the intermediate sacrificial layer to create abutments on each of the facing faces of the freed layer and the substrate.

[0017] Another such method is described in "Surface Roughness Modification of Interfacial Contacts in Polysilicon Microstructures", R. L. Alley et al., Proceedings of the 7th International Conference on Semiconductor Detectors and Actuators). That paper proposes a method of producing partially mobile components including steps leading to a component whose facing free faces have a roughness adapted to prevent unwanted sticking between said faces (see the paper for a statistical definition of roughness; for example, roughness may be measured using an atomic force microscope scanning areas 1 μm×1 μm, for example). During the step of chemical freeing of the structure, this method roughens the surfaces concerned in order for the effective area of contact to be limited to the summits of the asperities of those surfaces. The paper by R. L. Alley et al. is essentially concerned with assessing how the sticking force decreases when the roughness increases.

[0018] The method described in the above paper has the drawback that it cannot be used to produce certain types of components. In particular, the method provides for the deposition of a surface film on the substrate of the stacked structure; the person skilled in the art knows that this deposition is not always possible, for example depending on the materials concerned. For example, this method cannot produce a monocrystalline surface film to be freed if the material of the sacrificial layer is amorphous; nor can it produce a monocrystalline film, for example of silicon, on a sacrificial layer of a polymer material, because of the incompatibility of the temperature for depositing the silicon film and the temperatures that a polymer is usually able to withstand.

SUMMARY

[0019] The present invention therefore relates to a method of fabricating a stacked structure, where necessary of large size, and where applicable over the whole of the surface of a wafer having a diameter of 200 mm, for example, enabling subsequent production of any MEMS type component without sticking of mobile or deformable mechanical structures. The method must be applicable regardless of the characteristics of said components, in particular their size or the materials used, especially if the surface layer that has to be (at least partly) freed is monocrystalline or cannot be simply deposited onto the required stacked structure.

[0020] A first aspect of the invention therefore proposes a method of fabricating a stacked structure, the method being noteworthy in that it comprises the following steps:

[0021] a) a first plate and a second plate are selected such that at least one of said first and second plates has a structured surface, at least in part,

[0022] b) a sacrificial layer is produced on at least a portion of the surface of the first plate and/or the surface of the second plate, and

[0023] c) the two plates are bonded together.

[0024] Thus using the method of the invention produces a stacked structure comprising a sacrificial layer between two substrates and in which at least one of the two substrates is such that at least a portion of its surface in contact with said sacrificial layer is structured In the context of the invention, a surface is regarded as structured when it is essentially incapable of sticking to a predetermined other substrate. For example, a surface may be structured because of the physical-chemical nature of that surface or because of a coating applied to that surface; a surface may equally be structured because of a roughness exceeding a predetermined threshold, for example equal to approximately 0.2 nm root mean square (RMS).

[0025] Starting with the stacked structure obtained in this way, a portion of the intermediate sacrificial layer between the two plates may be eliminated, for example, to obtain two facing surfaces at least one of which is appropriately structured. This prevents the two surfaces sticking together following movement of the two substrates toward each other.

[0026] Note that, according to the invention, the structured surfaces are produced before or during fabrication of the stacked structure, and therefore independently of the fabrication of an MEMS type component.

[0027] Due to the invention, any set of materials that are subsequently useful in the production of an MEMS component may advantageously be selected to constitute the stacked structure. For example, a stack could be produced comprising a thin layer of silicon on a sacrificial layer of polymer or a thin layer of monocrystalline silicon on a sacrificial layer of silicon oxide. Note also that the method of the invention does not limit the lateral dimensions of the stacked structure obtained.

[0028] According to particular features of the invention, the free surface of a sacrificial layer or, where appropriate, of both sacrificial layers and/or, where appropriate, the free surface of one of said plates is smoothed before said step c).

[0029] These features facilitate subsequent bonding (step c)), which may be molecular bonding, for example, or bonding by means of a sacrificial bonding agent, i.e. a bonding agent that can be eliminated subsequently, for example during use of said stacked structure to fabricate a component comprising a mobile or deformable portion. Moreover, the bonding of the step c) can be assisted by mechanical means, for example, and/or by plasma and/or heat treatment, these operations being carried out during or after bonding, in a special atmosphere or in the ordinary atmosphere.

[0030] Due to these features, the diverse interfaces may in particular be consolidated and/or rendered compatible with future MEMS component production steps. Two rough surfaces that would not bond to each other spontaneously may also be made to bond in this way.

[0031] According to further particular features of the invention, at least one of said the two plates is thinned after the step c).

[0032] Due to these features, portions of an MEMS type component that become mobile after eliminating the sacrificial layer in contact therewith could be produced in the thin film obtained in this way, for example.

[0033] The two plates and the sacrificial layer may of course be either simple or composite, i.e. formed themselves of a stack of layers of diverse materials. The stacked structure obtained in this way may advantageously be of the SOI type.

[0034] For example, the first plate, and likewise the second plate, may be made of silicon, a semiconductor other than silicon, for example SiC, GaN or InP, or a non-semiconductor material, such as $LiNbO_3$, $LiTaO_3$, glass, fused silica or a superconductor material. The first plate, and likewise the second plate, may equally be any combination of the above materials, in particular a monocrystalline Si/polycrystalline Si stack, SiC/Si stack, InP/Si stack, monocrystalline SiC/polycrystalline SiC stack or SiC/SiO_2/polycrystalline SiC stack. The material constituting the sacrificial layer produced on the first plate and/or the material constituting the sacrificial layer produced on the second plate may be silicon oxide, for example, or a polymer material.

[0035] According to particular features, at least one of said plates initially has a surface layer. In particular, this surface layer may have the effect of structuring the surface of the plate on which it rests because of the physical-chemical nature of that surface layer.

[0036] A second aspect of the invention provides diverse stacked structures.

[0037] Firstly, the invention provides a stacked structure fabricated by any of the methods succinctly described hereinabove.

[0038] Secondly, the invention provides a stacked structure that is noteworthy in that it comprises a sacrificial layer between a first substrate and a second substrate and at least one of said first and second substrates has a surface that is structured, at least in part.

[0039] Of course, the two substrates and the sacrificial layer may be either simple or composite, i.e. formed themselves of a stack of layers of diverse materials. The stacked structure obtained in this way may be in particular of the SOI type.

[0040] For example, the first substrate, and likewise the second substrate, may be made of silicon, a semiconductor other than silicon, for example SiC, GaN or InP, or a non-semiconductor material, such as $LiNbO_3$, $LiTaO_3$, glass, fused silica or a superconductor material. The first substrate, and likewise the second substrate, may equally be any combination of the above materials, in particular a monocrystalline Si/polycrystalline Si stack, an SiC/Si stack, an InP/Si stack, a monocrystalline SiC/polycrystalline SiC stack, or an SiC/SiO_2/polycrystalline SiC stack. The material constituting the sacrificial layer may be silicon oxide, for example, or a polymer material.

[0041] According to other particular features of the invention, at least one of the two substrates is a thin layer.

[0042] The advantages offered by the above materials are essentially the same as those offered by the corresponding fabrication methods.

[0043] Other aspects and advantages of the invention will become apparent on reading the following detailed description of particular embodiments provided by way of nonlimiting example.

BRIEF DESCRIPTION OF DRAWINGS

[0044] The description refers to the appended drawings, in which:

[0045] **FIG. 1** represents a silicon plate prior to implementation of the invention,

[0046] **FIG. 2** shows the same silicon plate after application of a first step of one embodiment of a fabrication method of the invention,

[0047] **FIG. 3** represents a second step of that method,

[0048] **FIG. 4** represents a third step of that method,

[0049] **FIG. 5** represents a fourth step of that method,

[0050] **FIG. 6** represents a fifth step of that method.

DETAILED DESCRIPTION

[0051] The process starts with a standard silicon plate **1** whose surface **2** has a roughness r_2 which is usually of the order of 0.1 nm (**FIG. 1**).

[0052] The surface **2** of the plate **1** is then structured for example by creating a roughness r'_2 at the surface **2** that is preferably in the range from 0.2 nm to a few micrometers (**FIG. 2**). The roughness selected depends, among other things, on the thickness of the intermediate sacrificial layer, the geometrical parameters of the future component with mobile portions, and the stresses in the surface film, for example. The person skilled in the art will know how to determine the roughness to be used to prevent any unwanted sticking within the component.

[0053] To produce this roughness of the silicon surface, one or more etching steps may be effected, for example, using an RCA SC1 type mixture (H_2O: NH_4OH: H_2O_2 6:1:1 at 80° C.), and/or other wet chemical etching processes (for example using a solution of TMAH or KOH), and/or dry etching processes (such as reactive or non-reactive ion sputtering). Of the techniques for producing this roughness, the following in particular may be cited:

[0054] the technique of producing black silicon, as described for example in the paper "Plasma Surface Texturization for Multicrystalline Silicon Solar Cells", M. Schnell, IEEE, XXVIIIth Photovoltaic Conference, mechanical techniques, for example sand-blasting or grinding, techniques involving fracture in crystalline materials leaving rough substrates after fracture, as used in the Smart-Cut® process (involving implanting species and a fracture) or in the CANON Eltran® process (involving obtaining porous silicon and a fracture in the porous region), for example, chemical etching techniques well known to the person skilled in the art for producing porous materials, for example those applied to silicon, and deposition techniques, in particular deposition of silicon nitride Si_3N_4 by the PECVD process (note that a PECVD deposit is rougher than an LPCVD deposit).

[0055] During a second step, a sacrificial layer **3** is produced on the surface of the plate **1** (**FIG. 3**).

[0056] The layer **3** may be of silicon oxide, for example. In this case, it may be produced by thermal oxidation in a wet or dry atmosphere or by deposition (LPCVD, PECVD or any other appropriate deposition process). The roughness r_4 of the surface **4** of the layer **3** may be of the same order of magnitude as the initial roughness of the plate **1**, or higher (it is known in the art to increase the roughness by depositing successive films, the roughness increasing with the number of films deposited and their thickness), or lower, for example as a result of depositing a smoothing oxide (not shown) at a low temperature, flow of which on the surface may be brought about by appropriate heat treatment, for example.

[0057] However, in certain cases, it may be necessary to modify the roughness of the surface **4** of the layer **3** to facilitate the subsequent bonding step producing the stacked structure of the invention. To this end, a slightly lower roughness r'_4 may be produced, for example by carrying out a surface smoothing operation during a third step (**FIG. 4**), for example by light mechanical-chemical polishing and/or heat treatment in a special atmosphere and/or depositing a smoothing layer (not shown).

[0058] During a fourth step (**FIG. 5**), a second plate **5**, for example of polycrystalline silicon (which may have a surface layer **9** of another material, for example monocrystalline silicon or SiC), is bonded to the layer **3**, preferably by molecular bonding. Bonding may equally be effected by means of a sacrificial type of bonding agent, i.e. a bonding agent that may be selectively removed, for example a photosensitive polymer.

[0059] In the case of a surface roughness incompatible with spontaneous molecular bonding of the parts to be assembled to form the stacked structure of the invention, bonding assistance may advantageously be used, firstly by placing the surfaces in contact, where applicable after applying plasma treatment to the surfaces, and then by applying mechanical stress and/or heat treatment to the stacked structure in a special atmosphere or in the ordinary atmosphere.

[0060] Heat treatment applied during or after bonding additionally consolidates the various interfaces and/or renders them compatible with future MEMS component production steps.

[0061] Finally, during an optional fifth step, at least one of the two plates **1** and/or **5** (the plate **5** in **FIG. 6**) may be thinned to obtain a stacked structure **100**, for example of the SOI type. Thinning may be effected by any of the prior art methods, such as those described in the introduction.

[0062] Note that it is perfectly feasible, in a variant of the invention, to place the steps of the method of producing the microstructure, for example the etching of areas in the sacrificial layer in contact with the mobile portions, in the middle of the steps that have just been described, for example before the bonding step. In this case, the mobile portions may also be defined in the plate that is subsequently thinned before the bonding step; after bonding and thinning of the plate comprising the mobile portions, heat treatment may be applied to strengthen the bonding interface of the stacked structure with no pressure stresses (said areas underlying the mobile portions giving onto the surface).

[0063] The embodiment described above may be modified or generalized in various ways. In particular, the method may relate to the whole or only a portion of the surface of at least one of the plates or one of the films treated. For example, a predetermined structure may be obtained in a localized area using a lithographic process.

[0064] As mentioned above, a given surface may be structured without necessarily roughening it.

[0065] For example, if the other substrate is of silicon, the surface to be structured may be treated by nitriding.

[0066] Another example of this is depositing on the surface to be structured a layer of an anti-stick material, i.e. a material whose physical-chemical nature is such that it opposes subsequent unwanted sticking (the creation of roughness, surface treatment or production of an anti-stick layer techniques may be combined, of course).

[0067] Thus a surface layer **6** (not shown), for example of Si_3N_4, may initially be deposited onto a first plate **1** with any roughness. A roughness r'_2 may then be created on the surface **2** of that surface layer **6**, as explained above, for example by conforming a rough surface by deposition. However, instead of or in addition to this creation of roughness, the surface of the surface layer **6** may also be prepared to render it incompatible with unwanted sticking to the substrate intended to face the surface layer **6**; using prior art methods, for example, the surface of a surface layer **6** of Si_3N_4 may be rendered hydrophobic; materials other than silicon nitride Si_3N_4 may be used here, such as diamond, Al_2O_3 or ZrO_2.

[0068] The sacrificial layer **3** is then deposited onto the surface layer **6**, being adapted, as explained above, for bonding, for example molecular bonding, to the plate **5** (which in this embodiment is of silicon), where applicable after a step of leveling by means of mechanical-chemical polishing or heat treatment. If necessary, bonding may be assisted in the manner explained above. During the production of the mobile structure component, selective etching of the layer **3** frees the structured surface of the surface layer **6**: during this selective etching, using hydrofluoric acid, for example, the material used for the sacrificial layer **3**, for example silicon oxide SiO_2, is etched, whereas that used for the surface layer **6**, for example silicon nitride Si_3N_4, is not.

[0069] Embodiments are described above in which only the surface **2** of the first plate **1** is structured; however, it is clear that, within the context of the invention, it is feasible to structure the surface **7** (not shown) of the second plate **5** as well or instead (the latter plate comprising a surface layer **9**, where appropriate, as described above).

[0070] Moreover, in the embodiments described above, a sacrificial layer **3** is produced only on the first plate **1**; however, it is clear that, in the context of the invention, a sacrificial layer **8** (not shown) may instead or in addition be produced on the second plate **5**. The two plates are then bonded as described above, where appropriate after smoothing the surface **10** (not shown) of the sacrificial layer **8**.

[0071] It is clear that a non-continuous sacrificial layer may be obtained, for example by localized deposition or by etching; this enables areas already opened up to be defined in the stacked structure.

[0072] The methods described above may be applied to any structure including a thin layer adhering to a buried layer, for example of silicon oxide, to be sacrificed locally, the latter resting on a support that may be of a material other than silicon. Depending on the requirements of the intended application, the person skilled in the art will be able to combine the methods described above to produce specific stacked structures according to the invention.

[0073] Note, finally, that the surface structuring required by the invention is not necessarily homogeneous over the whole of the surfaces concerned: for example, in certain applications it may be advantageous to produce a surface whose structuring is divided at random or in accordance with a particular distribution over the surface of one of the plates.

[0074] While various embodiments of the invention have been described, it will be apparent to those of ordinary skill in the art that many more embodiments and implementations are possible within the scope of the invention. Accordingly, the invention is not to be restricted except in light of the attached claims and their equivalents.

1. Method of fabricating a stacked structure comprising:

a) selecting a first plate and a second plate such that a portion of at least one of the first and second plates has a structured surface,

b) producing a sacrificial layer on at least a portion of the structured surface of the first plate or the structured surface of the second plate, and

c) bonding the two plates together.

2. The method according to claim 1 wherein producing the sacrificial layer comprises producing at least a portion of the structured surface of the first plate and at least a portion of the structured surface of the second plate.

3. The method according to claim 1 wherein selecting a first plate and a second plate comprises selecting plates having predetermined physical-chemical properties.

4. The method according to claim 1 wherein selecting comprises selecting the surface having a roughness greater than a predetermined threshold.

5. The method according to claim 4 wherein selecting further comprises selecting the structured surface wherein the predetermined threshold is approximately 0.2 nm root-mean-square (RMS).

6. The method according to claim 1 wherein selecting comprises selecting at least one of the plates that initially includes a surface layer.

7. The method according to claim 6 wherein selecting further comprises selecting at least one of the plates wherein the surface layer comprises a monocrystalline surface layer.

8. The method according to claim 6 wherein selecting further comprises selecting at least one of the plates wherein the surface layer comprises silicon.

9. The method according to claim 6 further comprising structuring the surface by forming the surface layer having predetermined physical-chemical properties.

10. The method according to claim 9 where structuring the surface comprises structuring the surface because of a physical-chemical property of that surface layer.

11. The method according to claim 9 wherein forming the surface layer comprises forming a layer of silicon nitride.

12. The method according to claim 1 further comprising smoothing at least one of a free surface of the sacrificial layer or a free surface of at least one of the plates before the bonding.

13. The method according to claim 1 further comprising smoothing the free surface of the sacrificial layer and the free surface of at least one of the plates before the bonding.

14. A The method according to claim 1 wherein bonding comprises molecular bonding.

15. The method according to claim 1 wherein bonding comprises bonding with a sacrificial bonding agent.

16. The method according to claim 1 wherein bonding further comprises bonding assisted by at least one of a mechanical means a plasma treatment, or a thermal treatment.

17. The method according to claim 1 wherein the method further comprises applying a selected atmosphere before bonding.

18. The method according to claim 16 wherein assisting further comprises applying a selected atmosphere during bonding.

19. The method according to claim 16 wherein bonding further comprises exposing the two plates to an open air environment before bonding.

20. The method according to claim 16 wherein bonding further comprises bonding in an open air environment.

21. The method according to claim 1 further comprising thinning at least one of the first or second plates after bonding.

22. The method according to claim 1 wherein a major portion of at least one of the plates comprises a semiconductor material.

23. The method according to claim 22 wherein the major portion comprises silicon.

24. The method according to claim 1 wherein the sacrificial layer comprises silicon oxide.

25. The ethod according to claim 1 wherein the sacrificial layer comprises a polymer.

26. A stacked structure fabricated by a method according to claim 1.

27. A stacked structure comprising a sacrificial layer between a first substrate and a second substrate wherein at least a portion of at least one of the first or second substrates comprises a structured surface.

28. The stacked structure according to claim 27 wherein the structured surface comprises a surface having predetermined physical-chemical properties.

29. The stacked structure according to claim 27 wherein the structured surface comprises a surface having a roughness greater than a predetermined threshold.

30. The stacked structure according to claim 29 wherein the predetermined threshold is approximately 0.2 nm.

31. The stacked structure according to claim 27 wherein at least one of the first or second substrates has a surface layer.

32. The stacked structure according to claim 31 wherein the surface layer comprises a monocrystalline surface layer.

33. The stacked structure according to claim 31 wherein the surface layer comprises silicon.

34. The stacked structure according to claim 31 wherein the surface layer by comprises a material having predetermined physical-chemical properties.

35. The stacked structure according to claim 34 wherein the surface layer comprises silicon nitride.

36. The stacked structure according to claim 27 wherein a major portion of at least one of the first or second substrates comprises a semiconductor material.

37. The stacked structure according to claim 36 wherein the major portion comprises silicon.

38. The stacked structure according to claim 27 wherein the sacrificial layer comprises silicon oxide.

39. The stacked structure according to claim 27 wherein the sacrificial layer comprises a polymer.

40. The stacked structure according to claim 27 wherein at least one of the first or second substrates comprises a thin layer.

* * * * *

EXHIBIT C

UNITED STATES PATENT AND TRADEMARK OFFICE

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United States Patent and Trademark Office
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/565,621	07/25/2006	Hubert Moriceau	9905-37 (BIF116044/US)	2319

90678 7590 01/07/2010
Commissariat a l'Energie Atomique/BHGL
P.O. Box 10395
Chicago, IL 60610

EXAMINER	
PATEL, REEMA	
ART UNIT	PAPER NUMBER
2812	
MAIL DATE	DELIVERY MODE
01/07/2010	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No.	Applicant(s)	
	10/565,621	MORICEAU ET AL.	
	Examiner	Art Unit	
	REEMA PATEL	2812	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *3* MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☒ Responsive to communication(s) filed on *29 October 2009*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4)☒ Claim(s) *1,5-8 and 11-26* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☐ Claim(s) _____ is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12)☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☒ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☒ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____.
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

DETAILED ACTION

Continued Examination Under 37 CFR 1.114

1. A request for continued examination under 37 CFR 1.114, including the fee set forth in 37 CFR 1.17(e), was filed in this application after final rejection. Since this application is eligible for continued examination under 37 CFR 1.114, and the fee set forth in 37 CFR 1.17(e) has been timely paid, the finality of the previous Office action has been withdrawn pursuant to 37 CFR 1.114. Applicant's submission filed on 9/11/09 and 10/29/09 has been entered.

Specification

2. The amendment filed 10/29/09 is objected to under 35 U.S.C. 132(a) because it introduces new matter into the disclosure. 35 U.S.C. 132(a) states that no amendment shall introduce new matter into the disclosure of the invention. The added material which is not supported by the original disclosure is as follows: Figure 7 of the Drawings illustrates removal of the sacrificial layer (3) to expose the roughened plate surface (2). However, there is insufficient support for this amendment to the drawings.

3. In the Remarks (9/11/09), the Applicant states that the new Fig. 7 is supported by Substitute Specification, pg. 15, lines 8-32 and pg. 16, lines 1-10 which discloses that the plate "surface can be exposed by selective processing of the sacrificial layer" (Remarks, page 10). Firstly, these selective passages mostly talk about the previous Fig. 7, where a surface layer 6 is formed on a plate 1. This seems largely irrelevant in relation to the new Fig. 7 (10/29/09 amendment) because this involves a sacrificial layer (labeled as "3") on a plate 1.

4. The amendment to the Specification (10/29/09) modifies the paragraph on page 16, beginning at line 26 to discuss [the new] Figure 7. The Examiner does not find this passage supportive of the new Figure 7 in terms of introducing a non-continuous sacrificial layer which exposes part of a roughened surface of the first plate.

5. Applicant is required to cancel the new matter in the reply to this Office Action.

Claim Rejections - 35 USC § 112

6. The following is a quotation of the first paragraph of 35 U.S.C. 112:

> The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same and shall set forth the best mode contemplated by the inventor of carrying out his invention.

7. Claims 1, 5-8, and 11-26 are rejected under 35 U.S.C. 112, first paragraph, as failing to comply with the written description requirement. The claim(s) contains subject matter which was not described in the specification in such a way as to reasonably convey to one skilled in the relevant art that the inventor(s), at the time the application was filed, had possession of the claimed invention.

8. Claim 1, amended 11/19/08, still contains the limitation that the sacrificial layer is partly eliminated to "expose the surface portion such that the surface portion at least partially faces the second plate." As applicants point out in page 6 of the Remarks (11/18/08), the applicants' Specification discloses:

> "a portion of the intermediate sacrificial layer between the two plates may be eliminated, for example, to obtain two facing surfaces at least one of which is appropriately structured. This prevents the two surfaces sticking together following movement of the two substrates toward each other." (Substitute Specification, p 7, lines 20-25).

9. While this excerpt provides support for at least partially eliminating the sacrificial layer so that the plates face each other, there is no section in this excerpt or anywhere else in the Written Description or drawings that discloses the surface portion (roughened side of first plate) is exposed. In a semiconductor fabrication context, an "exposed" structure or layer is usually open to the air or other environment. In the instant invention, Figure 4 illustrates partially eliminating the sacrificial layer but does not disclose that the surface portion of the first plate is in any way exposed since there is a layer of sacrificial layer over the entire surface portion of the first plate. Claims 5-8 and 11-26 inherit the 35 U.S.C. 112 rejection based on their dependency on claim 1.

Claim Rejections - 35 USC § 102

10. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

11. Claim 26 is rejected under 35 U.S.C. 102(b) as being anticipated by Shimada et al. (U.S. 6,156,215; "Shimada").

12. Claim 26 is a product-by-process claim and as such, will be examined in accordance with the structural limitations implied by the method steps in claim 1, the method claim upon which is depends (MPEP 2113).

13. Regarding claim 26, Shimada discloses in Figures 1A-1F, a first plate (1) with a surface portion (3) having a roughness such that the surface portion is incapable of sticking to a surface of a second plate (8), wherein the surface portion of the first pate is

exposed and at least partially faces and is in close proximity to the second plate (Fig. 1E). Method claim 1 includes forming a sacrificial layer and at least partly eliminating the sacrificial layer. Hence, if this sacrificial layer is entirely removed, then there is no sacrificial in the final stacked structure.

Response to Arguments

14. Applicant's arguments filed 9/11/09 and 10/29/09 have been fully considered but they are not persuasive.

15. Regarding the claims 1, 5-8, and 11-26 rejection, Applicant argues that the term "faces" in claim 1 necessarily means that the roughened portion of the first place is opposite to the second plate with no intervening structures between the surfaces of the plates. The Examiner disagrees with this narrow interpretation of the word "face" and in the course of the broadest reasonable interpretation, interprets the word "face" to mean overlap but not necessarily with the limitation that there are no intervening layers.

16. Applicant attempts to support the narrow definition of the word "face" by referencing the Specificiation (Remarks, pg. 7) and particularly Figures 3 and 4. Examiner agrees that these figures disclose the sacrificial layer (3) but feels that they do not adequately support Applicant's definition of "faces" to indicate no intervening structures. Figures 3 and 4 do not even illustrate a second plate (5) and as such, they cannot disclose the surfaces and the second plates facing each other. Applicant further points to a passages in the (Substitute) Specification (pg. 7, lines 20-25) which indicates that the two plates have "facing surfaces" but this by itself does not offer support that "facing" in this context implies no intervening structures in between.

17. Applicant further asserts that one skilled in the art would understand "facing" to mean with no intervening structures in between based on the plain and ordinary meaning of the word "face" in Webster's Third New International Dictionary (Remarks, pg. 8). Applicant indicates the word 'face' is defined as "to stand or sit oppoite to" and the word 'opposite' is defined as "set over or against something that is at the other end or side of an intervening line or space." (Remarks, pg. 8). The Examiner still does not find adqequate support since something can be set over or on the other side of another thing with intervening materials in between.

18. Applicant asserts that they disclose processes in which at least a portion of the sacrificial layer (3) is removed (Remarks, page 8). The Examiner does not dispute this general premise but does not find that removal of at least a portion of sacrificial layer necessarily implies "exposing a portion of the rough surface of the underlying plate" (Remarks, page 8).

19. Regarding the claim 26 rejection, since the Examiner interprets the term "face" from claim 1 to not imply no intervening layers in between, the reference Shimada et al. used in rejection of this product-by-process claim does not require partially removing a peeling layer (4, Fig. 1E) or light blocking layer (5, Fig. 1E).

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to REEMA PATEL whose telephone number is (571)270-1436. The examiner can normally be reached on M-F, 8:00-4:30 ET.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Charles Garber can be reached on (571)272-2194. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/Walter L. Lindsay, Jr./
Primary Examiner, Art Unit 2812

/R. P./
Examiner, Art Unit 2812
12/31/09

EXHIBIT D

BRINKS
HOFER
GILSON
&LIONE

CERTIFICATE OF EFS FILING UNDER 37 CFR §1.8

I hereby certify that this correspondence is being electronically transmitted to the United States Patent and Trademark Office, Commissioner for Patents, via the EFS pursuant to 37 CFR §1.8 on the below date:

Date: September 11, 2009 Name: Jasper W. Dockrey, Reg. 33,868 Signature: /Jasper W. Dockrey/

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Appln. of:	Moriceau, et al.	
Appln. No.:	10/565,621	Examiner: Reema Patel
Filed:	July 25, 2006	Art Unit: 2812
For:	STACKED STRUCTURE AND PRODUCTION METHOD THEREOF	Confirmation No.: 2319
Attorney Docket No:	9905/37 (BIF116044US)	

AMENDMENT AND RESPONSE UNDER 37 C.F.R. § 1.114(c) AND SUBSTANCE OF INTERVIEW

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

In response to the Office Action of March 12, 2009 and the Advisory Action of August 5, 2009, in the above-referenced application, the applicants respectfully request reconsideration of the rejection in view the remarks presented herein.

An amendment to the drawing appears at page 2 of this paper.

An amendment to the specification appears at page 3 of this paper.

A listing of claims is set forth beginning at page 4 of this paper.

The applicants' remarks begin at page 7 of this paper.

Amendment to the Drawing:

Please add Figure 7 to the drawing as shown in the attached drawing sheet.

Amendment to the Specification:

On page 11, please replace the paragraph beginning at line 19 with the following amended paragraph:

Figure 6 represents a fifth step of that method[[.]],

On page 11, after line 19, please add the following paragraph:

Figure 7 illustrates the silicon plate of Figure 3, having a non-continuous sacrificial layer.

On page 16, please replace the paragraph beginning at line 26 with the following amended paragraph:

It is clear that a non-continuous sacrificial layer 3 may be obtained as shown in Figure 7, for example by localized deposition or by etching; this enables areas already opened up to be defined in the stacked structure.

Amendments to the Claims:

The following listing replaces all prior listing of claims in the application.

Listing of Claims:

1. (Previously presented) A method of fabricating a stacked structure comprising the following sequential steps:

a) selecting a first plate and a second plate such that a surface portion of the first plate has a roughness such that the surface portion is incapable of sticking to a surface of the second plate,

b) producing a sacrificial layer on at least a part of the surface of the first plate or the surface of the second plate, and

c) bonding the first and second plates together,

the method further comprising a step of at least partly eliminating the sacrificial layer to expose the surface portion such that the surface portion at least partially faces the second plate.

2. – 4. (Cancelled)

5. (Previously presented) The method according to claim 1 wherein selecting a first plate and a second plate further comprises forming the surface having a roughness by increasing the roughness of the selected first or second plate to greater than approximately 0.2 nm root-mean-square (RMS).

6. (Previously presented) The method according to claim 1 wherein selecting comprises selecting a least one of the plates that initially includes a surface layer.

7. (Previously presented) The method according to claim 6, wherein selecting further comprises selecting at least one of the plates wherein the surface layer comprises a monocrystalline surface layer.

8. (Previously presented) The method according to claim 6 wherein selecting further comprises selecting at least one of the plates wherein the surface layer comprises silicon.

9. – 10. (Cancelled)

11. (Previously presented) The method according to claim 1 further comprising forming a surface layer comprising silicon nitride on one of the first or second plates.

12. (Previously presented) The method according to claim 1 further comprising smoothing at least one of a free surface of the sacrificial layer or a free surface of at least one of the plates before the bonding.

13. (Previously presented) The method according to claim 1 further comprising smoothing the free surface of the sacrificial layer and the free surface of at least one of the plates before the bonding.

14. (Previously presented) The method according to claim 1 wherein bonding comprises molecular bonding.

15. (Previously presented) The method according to claim 1 wherein bonding comprises bonding with a sacrificial bonding agent.

16. (Previously presented) The method according to claim 1 wherein bonding further comprises bonding assisted by at least one of a mechanical means, a plasma treatment, or a thermal treatment.

17. (Previously presented) The method according to claim 1 wherein the method further comprises applying a selected atmosphere before bonding.

18. (Previously presented) The method according to claim 16 wherein assisting further comprises applying a selected atmosphere during bonding.

19. (Previously presented) The method according to claim 16 wherein bonding further comprises exposing the two plates to an open air environment before bonding.

20. (Previously presented) The method according to claim 16 wherein bonding further comprises bonding in an open air environment.

21. (Previously presented) The method according to claim 1 further comprising thinning at least one of the first or second plates after bonding.

22. (Previously presented) The method according to claim 1 wherein a major portion of at least one of the plates comprises a semiconductor material.

23. (Previously presented) The method according to claim 22 wherein the major portion comprises silicon.

24. (Previously presented) The method according to claim 1 wherein the sacrificial layer comprises silicon oxide.

25. (Previously presented) The method according to claim 1 wherein the sacrificial layer comprises a polymer.

26. (Previously presented) A stacked structure fabricated by a method according to claim 1.

27. – 41. (Cancelled)

REMARKS

Claims 1, 5-8, and 11-26 are pending in the application. No claims have been amended. The drawing has been amended to add a new figure to illustrate disclosed subject matter. Further, the specification has been amended to recognize the new figure. No new matter has been introduced by the amendment.

Rejection Under 35 U.S.C. 112, first paragraph

Claims 1, 5-8, and 11-26 have been rejected for allegedly failing to be supported by a written description of the invention. The applicants assert that this rejection is in error in view of the support for claim 1 provided in their specification. The applicants further assert that claim 1 is patentable over the cited references.

Claim 1 recites that the method includes "a step of at least partly eliminating the sacrificial layer such that the surface portion at least partially faces the second plate." In the context of claim 1, the term "faces" necessarily means that the roughed portion of the first plate is opposite to the second plate, with no intervening structure between the roughed portion of the first plate and the second plate. Accordingly, the claimed method differs from the prior art methods in which a sacrificial layer is planarized or surface portions are globally etched away.

The sacrificial layer is a layer that can be eliminated subsequently, such as during use of the stacked structure to fabricate a mobile or deformable component. (*See*, Specification, pg. 2, ll. 26-32, pg. 3, ll.1-6). An example of processing a sacrificial layer (3) is illustrated in FIG. 3 and 4 of the applicants' drawing. In the illustrated example, the sacrificial layer (3) covers the rough surface of the plate (1) (denoted as element 2 in FIG. 2). At least partial elimination of the sacrificial layer provides that, when the plates are brought together, the surface portion faces the other plate.

As described in the applicants' substitute specification:

> "a portion of the intermediate sacrificial layer between the two plates may be eliminated, for example, to obtain two facing surfaces at least one of which is appropriately structured. This prevents the two surfaces sticking together following movement of the two substrates toward each other." (Substitute Specification, pg. 7, lines 20-25).

The applicants assert that one skilled in the art would understand the meaning of the word "faces" as used in the applicants' specification and claims. The words of a claim must be given their plane and ordinary meaning unless such meaning is inconsistent with the specification. *See*, MPEP §2111.01 I. In the context of their claims, the applicants use the plain and ordinary meaning of the word "face," which is defined as: "to stand or sit opposite to." *Webster's Third New International Dictionary*, Merriam-Webster, Inc., 2002, pg.811, *vb*, 2a. In this context, the word "opposite" means "set over or against something that is at the other end or side of an intervening line or space: FACING." Id. at pg. 1583, *adj*, 1a. Dictionaries are often used to understand the plan and ordinary meaning of claim language. *See* MPEP §2111.01 III; *PODS Inc. v. Porta Stor Inc.*, 82 USPQ2d 1553,1558 (Fed. Cir. 2007)(the court consulted *Webster's Third New International Dictionary* to interpret the word "around"). Thus, the phrase "the surface portion at least partially faces the second plate" in claim 1 is understood to mean that the surface portion is opposite to the second plate and on the other side of an intervening line or space. Which necessarily defines the plates to be arranged without any intervening structure, as described above.

As noted above, the specification describes that the process of removing at least a portion of the sacrificial layer prevents the plates from sticking together. This necessarily implies that they would otherwise stick to one another as they are brought together, were it not for an intervening line or space. The intervening line or space can be created by at least partly eliminating the sacrificial layer, as described in the quoted portion of the applicants' specification above, and as recited in claim 1. Accordingly, the applicants assert that one of skill in the art would understand their claims to recite a method in which the roughed portion of the first plate is opposite to the second plate, with a space, or in other words, no intervening structure between the roughed portion of the first plate and the second plate.

The Office Action asserts that there is no description of exposing the roughened surface portion of the underlying plate. (Office Action, pg. 2). The applicants assert that they disclose processes in which at least a portion of the sacrificial layer (3) is removed, thereby exposing a portion of the rough surface of the underlying plate. In addition to

the plain and ordinary meaning, by way of their specification, the meaning of the term "faces" as it appears in the applicants' claims is readily understood.

The concept of etching the sacrificial layer is described in the context of various embodiments of the invention. For example, with respect to mobile structures in the disclosed devices, the applicants describe that:

> "it is perfectly feasible, in a variant of the invention, to place the steps of the method of producing the microstructure, for example the etching of areas in the sacrificial layer in contact with the mobile portions, in the middle of the steps that have just been described, for example before the bonding step." (Substitute Specification, pg. 14, lines 16-21).

The applicants describe the use of photolithographic techniques to restrict processing to only a portion of the plate.

> "The embodiment described above may be modified or generalized in various ways. In particular, the method may relate to the whole or only a portion of the surface of at least one of the plates or one of the films treated. For example, a predetermined structure may be obtained in a localized area using a lithographic process." (Substitute Specification, pg. 14, lines 29-32; pg. 15, lines 1-3).

The applicants describe that selective processing, such as deposition and etching, is used to selectively process the sacrificial layer. Prior to amending their specification, the paragraph, now amended, stated as follows:

> "It is clear that a non-continuous sacrificial layer may be obtained, for example by localized deposition or by etching; this enables areas already opened up to be defined in the stacked structure." (Substitute Specification, pg. 16, lines 26-29).

The applicants have amended their drawing to include a new figure, Figure 7, that illustrates the result of partially forming the sacrificial layer 3, or partially removing a portion of the sacrificial layer 3, to form the non-continuous sacrificial layer, illustrated in Figure 7. The applicants' amendment of the paragraph set forth above recognizes the

new Figure 7, which merely illustrates the condition originally described in the paragraph.

The stacked structure described above is made by bringing the plates together as described throughout the applicants' specification. In one embodiment of the invention, the plate could also have a surface layer overlying the plate, and this surface layer can be exposed by selective processing of the sacrificial layer. (*See*, for example, Substitute Specification pg. 15, lines 8-32; pg. 16, lines 1-10).

The foregoing notwithstanding, the applicants assert that their original claims recite a method in which a non-continuous sacrificial layer is formed. Original claim 1 appears in the applicants' certified English translation of their priority French patent application, now of record in the instant application and filed on November 14, 2007. Claim element b) of original claim 1 is relevant to the written description rejection. Element b) of claim 1, as it appeared in the applicants' priority French patent application No. 0308865 application and in their corresponding PCT application No. PCT/FR04/01858, is reproduced below.

> b) a sacrificial layer (3; 8) is produced on at least a portion of the surface (2) of the first plate (1) and/or the surface (7) of the second plate (5)

The applicants assert that their specification fully meets the written description requirement at least in view of their original claims. Their original claims recognize that only a portion of the sacrificial layer can be produced on the first or second plate. As noted in MPEP §2163.03, "there is a strong presumption that an adequate written description of the claimed invention is present in the specification as filed. *In re Wertheim*, 541 F.2d 257, 262, 191 USPQ 90, 96 (CCPA 1976). Consequently, rejection of an original claim for lack of written description should be rare."

The applicants assert that claims 1, 5-8, and 11-26 recite inventive subject matter fully supported by their specification in compliance with 35 U.S.C. §112, first paragraph, and that distinguishes over the cited references.

Rejection Under 35 U.S.C. 102(b)

Claim 26 has been rejected over Shimada et al. This rejection is overcome in view of the following remarks.

Shimada et al. disclose a first substrate (1) having a peeling layer (4) overlying the substrate surface and the dents (3) in the surface. A light blocking layer (5) partially covers the peeling layer. A second substrate (8) has a mask layer (10) covering a discontinuous surface, and a bonding layer (7) partially covering the mask layer. In the bonded structure illustrated by Shimada et al. in FIG. 1E, the peeling layer (4) and the mask layer (10) remain on facing surfaces of their respective substrates. Shimada et al. do not suggest or disclose at least partially removing either the peeling layer or the light blocking layer. Accordingly, Shimada et al. fail to suggest or disclose a roughed surface portion that at least partially faces the second plate.

Substance of Interview

On July 13, 2009, the applicant's representative conducted a telephone interview with Examiner Patel and Examiner Garber. The applicants wish to thank the Examiners for their courtesy in granting the Interview. The applicants' representative explained the applicants' position that the specification supports the method recited in claim 1, and the applicants' definition of the term "faces."

The applicants wish to point out that they are referring to the portion of their specification reproduced above (Substitute Specification, pg. 7, lines 20-25) as one particular example of their specification's description regarding the structural relationship of the first and second plates recited in claim 1. Further, the applicants have provided independent support for their assertion that they use the plain and ordinary meaning of the word "faces." Accordingly, the applicants respectfully disagree with the Examiner's statement in the Interview Summary that the applicants are using a "special definition." The portions of their specification indentified by the Examiner in the Interview Summary (also set forth above) describe various ways of removing the sacrificial layer, including partially removing portions of this layer in such a way that the roughened surface of the underlying plate is exposed. Taken as a whole, the specification provides support both explicitly and inherently for the applicants' claims.

Response to Advisory Action

Under existing legal precedent, the meaning of a term can be understood by looking at the words of the claims, the specification, prosecution history, and extrinsic evidence. See §MPEP 2111.01 III. The fact that other definitions may be available does not alter the situation where the applicants have adopted a particular meaning. The terms appearing in the claims should be read in the context of the specification. *Id.* The applicants have described and claimed their method, which includes forming a structure in which the sacrificial layer is at least partially removed. This necessarily provides a structure in which the roughened portion faces the opposite plate when the first and second plates are brought together to form the stacked structure.

Shimada et al. do not disclose at least partially eliminating a portion of a sacrificial layer to expose the surface portion, as recited by claim 1. Accordingly, Shimada et al. do not suggest or disclose a structure in which a roughed surface portion at least partially faces the second plate

The applicants have made a novel and non-obvious contribution of the art of stacked structure device fabrication. The claims at issue distinguish over the cited references and are in condition for allowance. Accordingly, such allowance is now earnestly requested.

Respectfully submitted,

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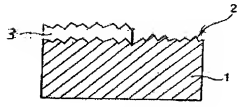

Fig. 7

EXHIBIT E

United States Patent [19]

Danel et al.

[11] **Patent Number: 4,653,326**

[45] **Date of Patent: Mar. 31, 1987**

[54] **DIRECTIONAL ACCELEROMETER AND ITS MICROLITHOGRAPHIC FABRICATION PROCESS**

[75] Inventors: **Jean-Sebastien Danel**, Grenoble; **Gilles Delapierre**, Seyssinet; **France Michel**, Sassenage, all of France

[73] Assignee: **Commissariat a l'Energie Atomique**, Paris, France

[21] Appl. No.: **686,902**

[22] Filed: **Dec. 27, 1984**

[30] **Foreign Application Priority Data**

Jan. 12, 1984 [FR] France 84 00414

[51] Int. Cl.⁴ G01P 15/125

[52] U.S. Cl. ..... 73/517 R; 73/517 B

[58] Field of Search ..... 73/517 AV, 517 R, 517 B, 73/510

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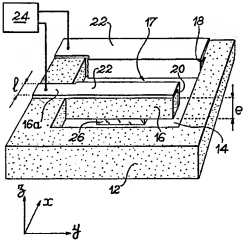
Jolly et al., 'Miniature Cantilever Beams Fabricated by Arisotropic Etching of Silicon', Dept. of Electrical Engineering, U. of California, Berkeley, Mar., 1980.

Primary Examiner—Stewart J. Levy
Assistant Examiner—Scott M. Oldham
Attorney, Agent, or Firm—Oblon, Fisher, Spivak, McClelland & Maier

[57] **ABSTRACT**

A directional accelerometer and a process for the microlithographic fabrication of such an accelerometer. The accelerometer includes a substrate having at least one recess to define at least one beam in the substrate. One of the ends of the beam is integrally formed with the remainder of the substrate. The beam, which is oriented in the first direction, is deformable into the recess in a second direction only, parallel to the substrate surface and perpendicular to the first direction. The second direction corresponds to the acceleration component to be measured. Electrical connections and contacts are formed in the substrate for the device measuring the deformations of the beam. These measurements make it possible to determine the acceleration components.

25 Claims, 5 Drawing Figures



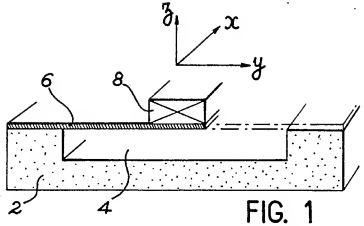


FIG. 1
PRIOR ART

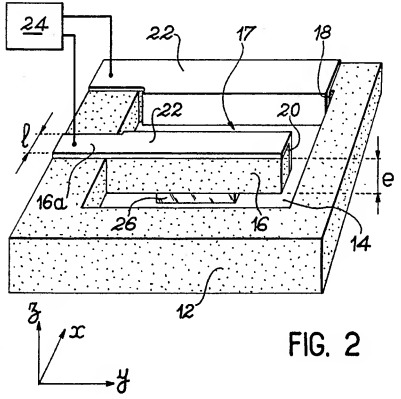


FIG. 2

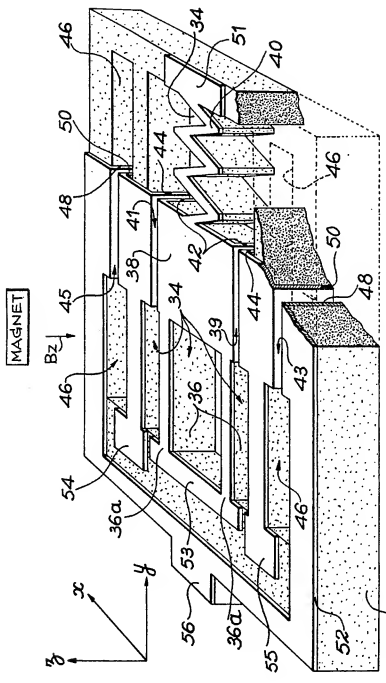

MAGNET
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FIG. 3

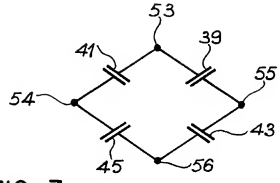

FIG. 3a

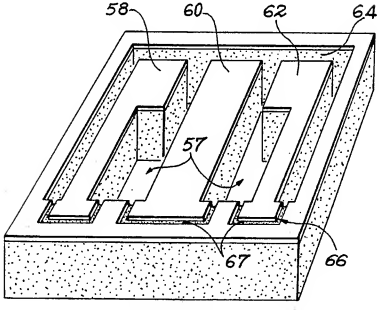

FIG. 4

DIRECTIONAL ACCELEROMETER AND ITS MICROLITHOGRAPHIC FABRICATION PROCESS

BACKGROUND OF THE INVENTION

The present invention relates to a directional accelerometer and its microlithographic fabrication process. As its name indicates, the directional accelerometer makes it possible to measure a single component of the acceleration of a moving body.

Generally, an accelerometer essentially comprises a moving mass m (pendulum) and means making it possible to measure the force F=my due to the acceleration γ of a moving body.

The presently commercially available accelerometers comprise detachable mechanical parts. The volume of such accelerometers is very large, in view of the large number of parts which form the same, as well as their complex manufacturing technology, particularly taking account of the problem of positioning the various elements constituting said accelerometers and the assembly thereof.

The use of techniques resulting from semiconductor technology is at present being developed with the aim of reducing the size of such accelerometers, together with their production costs, particularly by batch fabrication on the same flat substrate. Such an accelerometer fabrication procedure is described in an article by K. PETERSEN by Proceedings of the IEEE, Vol. 70, No. 5, May 1982.

In FIG. 1 is shown in longitudinal sectional form, the basic diagram of an accelerometer constructed in accordance with this novel procedure. The accelerometer comprises a substrate 2, made e.g. from silicon or glass, which has a recess 4. Onto the upper surface of the substrate is deposited, e.g. by vacuum deposition, a flexible thin layer 6 in the form of a beam and more particularly made from silica, doped silicon or metal, which overhangs the recess 4 formed in the substrate. This beam, which is able to deform or move in a direction perpendicular to the surface of the substrate represented by direction z, supports at its free end a seismic mass 8.

The measurement of the displacement of mass 8, which is proportional to the component of the acceleration in direction z which it is wished to measure, either takes place through the measurement of the variation of the capacitance of the capacitor defined by the thin layer 6 in the form of a beam and substrate 2, or with the aid of a piezoresistive element attached to said thin layer.

The above accelerometer in fact corresponds to what can best be done at present on a silicon plate, but suffers from a number of disadvantages. In particular, the flexible beam 6 can give rise to internal stresses leading to the bending of the beam, even when there is no acceleration. These stresses, which are very difficult to control, are particularly due to the accelerometer fabrication process. In addition, these stresses vary with the temperature.

Another disadvantage is caused by the stack of different materials, which have different expansion coefficients and which also lead to the formation of inadmissible stresses.

Moreover, as the mass 8 attached to the flexible beam 6 is off center with respect to the beam axis, this type of accelerometer is also sensitive to the component of the acceleration in a direction parallel to the surface of substrate 2, such as direction y. However, a good directional accelerometer must only be sensitive to a single component of the acceleration to be measured. This phenomenon is further aggravated when the beam 6 bends in the absence of acceleration, due to stresses within the actual beam.

Moreover, due to the lack of symmetry of the structure of the accelerometer, it is very difficult to perform a differential measurement of the displacement of mass 8. However, it is not possible to carry out a precise measurement of the position of the beam without such a procedure.

In order to obviate this lack of symmetry, it would be possible to join a second symmetrical substrate to the first with respect to the thin layer 6. Such a device is described in the article in IEEE Transactions on Electron Devices, Vol. ED-26, No. 12, December 1979, New York 45A, pp. 1911–1917 entitled "A batch fabrication silicon accelerometer" by L. N. ROYLANCE et al. In the case of said device, the problem of internal stresses occurs at the actual substrate, as a result of the sealing. In addition, this process is complicated and costly.

Another disadvantage of these accelerometers is their limited sensitivity. Thus, the dimensions of the thin layer 6 in the form of a beam are fixed, so that it is difficult to increase the seismic mass 8, the latter having at the most a thickness of a few microns.

A possible variant of the accelerometer shown in FIG. 1 consists of having two ends of a thin layer 6 fixed to the substrate, which makes it easier to fix the starting position of mass 8, even when there are stresses within the said layer. However, such an accelerometer has a much more rigid structure and consequently a reduced sensitivity.

SUMMARY OF THE INVENTION

The object of the present invention is to provide a directional accelerometer and its fabrication process, which are based on microelectronics technology, i.e. permitting a batch fabrication on the same substrate, whilst obviating the disadvantages referred to hereinbefore.

More specifically, the present invention relates to a directional accelerometer making it possible to measure one component of the acceleration of a moving body, wherein it comprises a substrate having at least one recess defining at least one beam in the substrate, whereof one of the ends is integral with the remainder of the substrate, said beam which is oriented in a first direction being able to deform in a single direction, called the second direction in the said recess and which is parallel to the surface of the substrate and perpendicular to the first direction, said second direction corresponding to the component of the acceleration to be measured, as well as contacts and electrical connections on the substrate used for connecting means for measuring deformations of the said beam, said measurements making it possible to determine the value of said component of the acceleration.

This accelerometer makes it possible to measure one component of the acceleration directed parallel to the surface of the substrate, whereas the prior art accelerometers made it possible to measure one component of the acceleration directed perpendicular to the surface of the substrate.

Moreover, due to the fact that the beam is directly machined into the substrate, the problems of multiple substrates or stacks of layers are eliminated, which makes it possible to considerably reduce the mechanical stresses of the accelerometer and provide an accelerometer having an excellent thermal stability.

According to a preferred embodiment of the accelerometer according to the invention, the means for measuring deformations of the substrate are realised in the substrate.

Varied acceleration measuring ranges can easily be obtained by acting on the dimensions and shape of the beam, or by possible additions of masses, whilst maintaining the symmetry of the accelerometer. Advantageously, the beam of the accelerometer according to the invention has a much larger thickness dimension than width dimension, which makes it possible to obtain a very directional accelerometer.

Moreover, according to a preferred embodiment of the accelerometer according to the invention, the free end of the beam is able to support a block formed in the substrate and able to move into the recess of the substrate, in said second direction, under the action of the component of the acceleration to be measured. This makes it possible to obviate the need for joining a seismic mass, particularly electrolytically, as was the case with the prior art accelerometers.

Obviously, the accelerometer substrate can be made from any random material and preference is given to the use of monocrystalline α quartz (the crystalline structure of quartz which occurs below 537° C.) or silicon for the same.

According to a preferred variant of the invention, the accelerometer comprises a spring, formed in the substrate, located in the extension of the block and connecting the latter to the remainder of the substrate in the first direction.

According to a preferred embodiment of the accelerometer according to the invention, the measuring means comprise at least one variable capacitance capacitor defined by a surface of the block and generally transverse to the second direction, a substrate surface facing said block surface, said surfaces being covered by a metal layer, and by the space located between said metallized surfaces.

Advantageously, these measuring means also comprise at least one constant capacitance capacitor defined by another recess formed in the substrate, having two facing surfaces, generally transverse with respect to the second direction and covered with a metal layer.

As a result of this constant capacitance capacitor, it is possible to perform a differential measurement of the deformations of the beam and/or the block, in this way leading to a precise measurement of the component of the acceleration to be measured, which was difficult with the prior art accelerometers.

The present invention also relates to a process for the production of microlithography of a directional accelerometer of the type defined hereinbefore, wherein it comprises the stages of forming a mask on the substrate making it possible to define the shape of the different elements of the accelerometer formed in the substrate, etching regions of the substrate which are free from the mask and forming contacts and electrical connections for the accelerometer and means for measuring deformations of the beam.

In this fabrication process, the stresses at the conductor-substrate interface act perpendicular to the substrate, i.e. perpendicular to the sensitive axis of the accelerometer and not along the same, as was the case in the prior art accelerometers. Thus, there is a total absence of twisting or deformation of the moving elements of the accelerometer when there is no acceleration, together with an excellent thermal stability of the accelerometer.

Advantageously, the substrate is etched by a dry etching process and particularly by reactive ionic etching, which can be advantageously used on any random type of material forming the accelerometer substrate. Moreover, this type of etching has the advantage of fixing the shape of the accelerometer elements formed in the substrate through the shape of the mask, whilst being independent of the crystal orientation of the substrate.

According to a variant of the process, it is also possible to use anisotropic chemical etching in the case where the substrate is monocrystalline (silicon, quartz). However, in this case, if straight sided beams are required, the crystal orientation of the substrate cannot be of a random nature.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention is described in greater detail hereinafter relative to non-limitative embodiments and with reference to the attached drawings, wherein show:

FIG. 1, already described, in longitudinal section the basic diagram of a prior art directional accelerometer.

FIG. 2 a perspective view illustrating the principle of the accelerometer according to the invention.

FIG. 3 a perspective view of a special embodiment of the accelerometer according to the invention, FIG. 3a showing its electrical equivalent.

FIG. 4 a special embodiment of the fabrication process of the accelerometer according to the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 2 is a perspective view of the basic diagram of the accelerometer according to the invention, which comprises a substrate 12, which is preferably formed from an insulating material such as silicon, silica or monocrystalline α quartz, which has a recess 14 passing completely through the substrate. Within the substrate, recess 14 defines a flexible beam 16, whose ends 16a are integral with the remainder of the substrate. This beam 16, which is oriented in a direction y parallel to the upper surface of substrate 12, can deform in a direction x parallel to said substrate surface and perpendicular to direction y, direction x corresponding to the direction of the acceleration component to be measured. The measurement of the deformations of displacements of beam 16 in direction x makes it possible to determine the value of the acceleration component in said direction, said deformations being proportional to the value of said component.

Through machining the flexible beam 16 directly in substrate 12, it is possible to overcome problems caused by the use of multiple layers in the prior art accelerometers.

Advantageously, the means making it possible to measure the deformations of beam 16 when the latter is subject to an acceleration can be formed in substrate 12. These means can in particular be constituted by a variable capacitance capacitor 17, defined by recess 14 and for this purpose having two metallized lateral surfaces, e.g. 18 and 20, which face one another and which are

oriented parallel to direction y. The deposition of conductive strips 22 on the upper surface of the substrate 12 makes it possible to connect the variable capacitance capacitor 17 to a conventional measuring system 24, which makes it possible to determine variations of the capacitance of said capacitor.

On the basis of these measurements, it is easy to determine the values of the component in acceleration direction x of a body, designated γ_x, with the aid of the formula

$$\gamma_x=(K/m)\times(\epsilon_0 S/C)\times(\Delta C/C),$$

in which ϵ_0 is the dielectric permittivity of the vacuum, S the surface of the capacitor coatings, K the rigidity constant of the beam, m its mass, C the capacitance of the capacitor and ΔC the capacitance variation. The various connections and metallizations of the accelerometer can be realised in a double chrome and gold layer.

So as to obtain a very directional accelerometer i.e. only making it possible to measure the acceleration component of a body in direction x, beam 16 must have a much larger thickness dimension e than width dimension l, as shown in FIG. 2.

Taking account of the symmetry of the accelerometer and the thickness of beam 16, it is always possible to add one or more seismic masses such as 26 to the beam. The addition of one or more seismic masses 26 makes it possible to considerably increase the accelerometer sensitivity.

FIG. 3 is a perspective view of a special embodiment of the accelerometer according to the invention. The accelerometer comprises a substrate 32, e.g. made from silicon or monocrystalline α quartz of section z (section along z axis), in which is formed a recess 34 passing entirely through the substrate and inter alia defining therein, two flexible beams 36, whereof one of the ends 36α is integral with the remainder of substrate 32. These beams 36, which are oriented in a direction y parallel to the upper surface of substrate 32, can move or rather deform in a direction x parallel to the surface of the substrate and perpendicular to said direction y. Direction x corresponds to the direction of the acceleration component to be measured.

These two beams 36, which have a much greater thickness than width, support at their free end a block 38, which is e.g. shaped like a rectangular parallelepiped, whose thickness is equal to that of the beams. This block 38, formed in substrate 32, can move or rather deform in recess 34 in the substrate in direction x. This accelerometer also comprises a spring 40, formed in the substrate and located in the extension of block 38 symmetrically with respect to beams 36, so that the latter can be joined to the remainder of substrate 32. This spring 40, which is oriented in direction y and has a thickness equal to that of beams 36 makes it possible to electrically connect the electrodes deposited on the moving parts (beams, blocks) of the accelerometer, without making the accelerometer structure rigid in such a way that its sensitivity would be reduced.

The means for measuring the deformations of block 38 in direction x are also formed in substrate 32. These means more particularly comprise two identical variable capacitance capacitors 39, 41, which are defined by the lateral faces 42 of block 38, i.e. the faces of the block oriented parallel to direction y by the surfaces 44 of recess 34 facing the said lateral faces 42 of the block, said surfaces 44 and 42 being covered by a metal layer, and by the space located between the metallized surfaces 42 and 44. The measurements of the variations of the capacitance of the thus defined capacitors make it possible to determine the deformations of block 38 in direction x, when the latter is subject to an acceleration in this direction.

In order to carry out a differential measurement of the deformations of block 38, the accelerometer according to the invention can be provided with one or more constant capacitance capacitors 43, 45. To this end, the accelerometer comprises recesses such as 46, formed in substrate 32 and located on either side of recess 34 in direction y. These recesses 38 have two facing surfaces respectively 48 and 50, oriented in direction y and covered with a metal layer. The metallized surfaces 48, 50 of recess 46, as well as the space between these two surfaces, define the constant capacitance capacitors 43, 45. This space has the same dimensions (thickness, width and length) as that between the metallized surfaces 42, 44.

The deposition of a metal layer 52 on the upper surface of substrate 32 makes it possible to produce the various contacts 53, 54, 55, 56 and electrical connections of the variable capacitance capacitors 39, 41 and constant capacitance capacitors 43, 45. This metal layer 52 must have an adequate shape to ensure that there are no short-circuits between the different capacitors.

FIG. 3α shows an electrical diagram illustrating the capacitance bridge of the accelerometer of FIG. 3. Deformations of block 38 are detected by measuring the unbalance of the capacitance bridge, as shown in FIG. 3α.

It is advantageously possible to utilize the measurement of this unbalance for exerting an opposing force F_x in direction x to force $F=my$ due to the acceleration γ, so as to make the unbalance of the bridge 0 (servo-system). One of the possible means for exerting the said force F_x consists of applying a magnetic field B_z perpendicular to the surface of the substrate and a current of intensity I_y in direction y between points 53 and 51. The feedback force is then given by the equation $F_x=B_z\times I_y\times l$, l being the length of the current on which B_z acts. In this case, the capacitive detection is used for zero detection (block at rest) and the electric current in the system formed by the beams, block and spring makes it possible to balance the acceleration effect to be measured at block 38, as a result of the action of magnetic field B_z. The determination of the acceleration then takes place by that of the current necessary for balancing the capacitance bridge (FIG. 3α), the intensity I_y of said current being directly proportional to the acceleration value.

It should be noted that the detection means described hereinbefore can be used for measuring both accelerations and decelerations.

Moreover, the detection system described hereinbefore is only one possible embodiment of the measuring means. Other means, based on the use of piezoresistors deposited on the upper surface of the substrate or based on optical detection procedures can also be used.

In order to cover a varied acceleration range, it is possible to vary the dimensions of seismic mass 26 by merely changing the shape of the etching mask.

A description will now be given of the process for the fabrication of an accelerometer according to the invention, which uses microlithography.

The different elements of the accelerometer formed in the substrate, such as beams 16 or 36, block 38 and spring 40, as well as the measuring means can be formed by etching substrate 2 or 32 in which the said elements are produced. The said etching is e.g. a dry etching process, such as reactive ionic etching or anisotropic wet etching, can be carried out by using a mask, preferably formed from a conductive material such as a double layer of gold and chrome, which covers the upper surface of the substrate and makes it possible to define the exact shape of the different accelerometer elements.

In the case of dry etching, there is a limitation of an etching depth of a few dozen microns and the width of the beam must be a few microns, if a good directivity is to be obtained. In this case, an interesting substrate can be constituted by silica obtained by thermal growth on silicon. After the etching process has passed through the silica, it is possible to disengage the rear of the beam by chemically etching the silicon, which supports the silica. The advantage of this process it that it can be used on an integrated silicon circuit.

According to another variant, it is possible to only chemically etch the substrate, but in this case there is a dependence on the crystalline anisotropy of the substrate. By acting on said anisotropy and that of the chemical etching product, it is possible to obtain the desired shape of the different elements forming the accelerometer. Good candidates for this method are α quartz of section z (axis z perpendicular to the plane of the substrate) and monocrystalline silicon for forming the substrate. In the case of quartz, use will e.g. be made of a mixture of HF and NH_4F as the etching product at 90° C.

The different contacts and electrical connections of the accelerometer formed on the substrate surfaces can be obtained either after eliminating the mask used for etching the substrate by appropriate metallization of the etched substrate surface, or by adequate metallization of the substrate before forming the etching mask on the then metallized substrate.

Another method for obtaining these contacts and connections consists of producing a conductive mask on the substrate, preferably in the form of a double layer of chrome and gold, which makes it possible to obtain both the shapes of the different accelerometer elements formed in the substrate and to produce said electrical connections and contacts.

FIG. 4 shows the principle of the single mask making it possible to define both the shape of the substrate elements of the accelerometer and produce the electrical connections and contacts thereof. This mask is formed by a conductive layer covering the upper surface of the substrate and having conductive strips such as 58, 60, 62 with the shape of the different accelerometer elements, which are formed in the substrate and which are to be provided with the electrical connections and contacts, as well as an adequately shaped recess 64 revealing the regions of substrate 57 which are to be etched in order to free the different elements of the accelerometer. Moreover, in the substrate regions which are not to be etched, the mask has very fine grooves making it possible to electrically separate the different accelerometer connections.

The existence of these grooves which form a grid 66 makes it possible, during the etching of the substrate, to etch the same to a very limited depth at the grid, the etching operation coming up against crystal planes at a very low etching speed so that a good mechanical stability is maintained. This slight substrate etching is represented by notches such as 67. This substrate etching depth difference is dependent on the size of the mask patterns, as well as the crystalline anisotropy of the substrate. Thus, when the mask patterns are large (patterns 57), there is a depth etching, whereas when the patterns are small (grid 66), substrate etching is only superficial.

The final stage of the accelerometer fabrication process consists of producing vertical metallizations making it possible to define the constant capacitance of variable capacitance capacitors after mechanically masking the substrate. For this purpose, it is advantageously possible to use vacuum evaporation with an incidence angle of the evaporation medium on the substrate which differs from 90°.

The process according to the invention makes it possible to produce in batch form a plurality of directional accelerometers on the same substrate, which are able to measure varied acceleration or deceleration ranges.

What is claimed is:

1. A monodirectional accelerometer for measuring one component of an acceleration of a moving body, comprising:

a substrate formed of a material and having at least one recess;

at least one parallelepipedic beam placed in the recess and having a first end which is integral with said substrate, said beam being formed of said material, being oriented in a first direction, having a width in a second direction and being able to deform in the second direction in said recess and having a thickness higher than its width, said thickness being oriented in a third direction perpendicular to said first and second directions so that said beam is only deformable in said second direction, said second direction being parallel to the surface of said substrate and perpendicular to said first direction, said deformation in said second direction corresponding to said component of said acceleration to be measured;

means for measuring deformations of said beam in said second direction to determine the value of said component of said acceleration; and

electrical contacts formed on said substrate for connecting said means for measuring with said beam.

2. An accelerometer according to claim 1, wherein the measuring means are formed in the substrate.

3. An accelerometer according to claim 1, wherein the other end of the beam supports a block, which is formed in the substrate and is able to move in the substrate recess in the second direction under the action of said acceleration component.

4. An accelerometer according to claim 3, wherein it comprises a spring, formed in the substrate and arranged in the extension of the block, connecting the latter to the substrate in the first direction.

5. An accelerometer according to claim 3, wherein the measuring means comprise at least one variable capacitance capacitor defined by a surface of the block and which is generally directed transversely to the second direction, a surface of the substrate facing said surface of the block, said surfaces being covered with a metal layer, and by the space located between said metallized surfaces.

6. An accelerometer according to claim 5, wherein the measuring means comprise at least one constant capacitance capacitor defined by another recess formed

in the substrate, which has two facing surfaces, which are generally directed transversely to the second direction and which are covered by a metal layer.

7. An accelerometer according to claim 1, wherein the substrate is formed from silica deposited on silicon.

8. An accelerometer according to claim 1, wherein the substrate is made from monocrystalline α quartz or silicon.

9. An accelerometer according to claim 5, wherein the measuring means comprise means making it possible to produce a magnetic field perpendicular to the surface of the substrate.

10. A process for the fabrication of a monodirectional accelerometer used for measuring one component of an acceleration of a moving body, said component being parallel to a first direction, said accelerometer comprising a substrate having at least one recess, at least one parallelepipedic beam placed in the recess and having a first end which is integral with said substrate, said beam oriented to a second direction parallel to a surface of said substrate and perpendicular to said first direction being able to deform only in said first direction and having a thickness higher than its width, said thickness being oriented to a third direction perpendicular to said first and second directions and said width being oriented to said first direction, measuring means for measuring deformations of said beam in said first direction and electrical contacts formed on said substrate for connecting said measuring means with said beam, said process comprising the following stages:

forming on said substrate a mask which defines the shape of said recess, said beam and in particular the width of said beam,

etching mask-free substrate regions in said third direction in order to form said recess and beam, the thickness of said beam being defined by said etching,

forming said measuring means,

eliminating said mask and

metallizing the etched substrate in order to produce said electrical connections and contacts.

11. A process according to claim 10, wherein the substrate is etched by a dry etching process.

12. A process according to claim 10, wherein the substrate is etched by means of a chemical etching process.

13. A process according to claim 10, wherein the mask is formed from a conductive material.

14. A process according to claim 13, wherein the mask is made from a double layer of chrome and gold.

15. A process according to claim 10, wherein the measuring means comprise capacitors and metallization takes place by vacuum deposition on the substrate surfaces which are used for defining said capacitors, following the mechanical masking of the substrate.

16. A process for the fabrication of a monodirectional accelerometer used for measuring one component of an acceleration of a moving body, said component being parallel to a first direction, said accelerometer comprising a substrate having at least one recess, at least one parallelepipedic beam placed in the recess and having a first end which is integral with said substrate, said beam oriented to a second direction parallel to a surface of said substrate and perpendicular to said first direction being able to deform only in said first direction and having a thickness higher than its width, said thickness being oriented to a third direction perpendicular to said first and second directions and said width being oriented to said first direction, measuring means for measuring deformations of said beam in said first direction and electrical contacts formed on said substrate for connecting said measuring means with said beam, said process comprising the following stages:

metallizing the substrate surface in order to produce said electrical connections and contacts,

forming on said metallized substrate a mask which defines the shape of said recess, said beam and in particular the width of said beam,

etching mask-free substrate regions in said third direction in order to form said recess and beam, the thickness of said beam being defined by said etching,

forming said measuring means and

eliminating said mask.

17. A process according to claim 16, wherein the substrate is etched by a dry etching process.

18. A process according to claim 16, wherein the substrate is etched by means of a chemical etching process.

19. A process for the fabrication of a monodirectional accelerometer used for measuring one component of an acceleration of a moving body, said component being parallel to a first direction, said accelerometer comprising a substrate having at least one recess, at least one parallelepipedic beam placed in the recess and having a first end which is integral with said substrate, said beam oriented to a second direction parallel to a surface of said substrate and perpendicular to said first direction being able to deform only in said first direction and having a thickness higher than its width, said thickness being oriented to a third direction perpendicular to said first and second directions and said width being oriented to said first direction, measuring means for measuring deformations of said beam in said first direction and electrical contacts formed on said substrate for connecting said measuring means with said beam, said process comprising the following stages:

forming on said substrate a conductive mask which defines the shape of said recess, said beam and in particular the width of said beam and which produces said electrical connections and contacts, said mask being shaped like a grid, of which bars have a limited spacing in the substrate regions which are to be free from said electrical connections,

etching mask-free substrate regions in said third direction in order to form said recess and beam, the thickness of said beam being defined by said etching, and

forming said measuring means.

20. A process according to claim 19, wherein the substrate is etched by a dry etching process.

21. A process according to claim 19, wherein the mask is formed from a conductive material.

22. A process according to claim 21, wherein the mask is made from a double layer of chrome and gold.

23. A process according to claim 19, wherein the substrate is etched by a dry etching process.

24. A process according to claim 19, wherein the substrate is etched by means of a chemical etching process.

25. A monodirectional accelerometer for measuring component of an acceleration of a moving body, comprising:

a substrate formed of a material and having at least one recess;

at least one parallelepipedic beam placed in the recess and having a first end which is integral with said substrate, said beam being formed of said material, being oriented in a first direction and being able to deform in a second direction in said recess and having a thickness higher than its width so that said beam is only deformable in said second direction, said second direction being parallel to the surface of said substrate and perpendicular to said first direction, said deformation in said second direction corresponding to said component of said acceleration to be measured;

said beam having a second end which supports a block, said block being formed in said substrate and being able to move in said recess in the second direction, said block being connected to the substrate in the first direction with a spring which is formed in the substrate;

means for measuring deformations of said beam in said second direction to determine the value of said component of said acceleration; and

electrical contacts formed on said substrate for connecting said means for measuring with said beam.

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